

REMARKS

Applicants are amending their claims in order to further clarify the definition of various aspects of the present invention. Specifically, Applicants are amending claim 1 to recite that the remaining second portion of the first diluted raw material gas is discharged without flowing through the reaction chamber. Note, for example, section [0041], bridging pages 38 and 39 of Applicants' specification.

In addition, Applicants are adding new claim 21 to the application. Claim 21, dependent on claim 1, recites that the remaining second portion is discharged from a vent line, consistent with the description in the paragraph bridging pages 38 and 39 of Applicants' specification. It is respectfully submitted that newly added claim 21 reads on the elected Group I, Specie I, and is to be considered on the merits in the above-identified application.

Withdrawal from consideration of claims 6 and 13-15, set forth in Item 3 on page 2 of the Office Action mailed August 19, 2008, is noted. Note also that claims 6 and 13-15 are dependent ultimately on claim 1; and it is respectfully submitted that upon allowance of claim 1, claims 6 and 13-15 should be re-joined in the above-identified application and be allowed to issue in a U.S. patent issuing therefrom.

Applicants respectfully submit that all claims presently pending in the above-identified application, and in particular those being considered on the merits therein, patentably distinguish over the teachings of the references applied by the Examiner in rejecting claims in the Office Action mailed August 19, 2008, that is, the teachings of the U.S. patent documents to Sukegawa, et al., Patent Application Publication No. 2003/0162370, and to Takahashi, et al., Patent No. 6,306,211, under the provisions of 35 USC 102 and 35 USC 103.

It is respectfully submitted that these references as applied by the Examiner would have neither disclosed nor would have suggested such a manufacturing method of a semiconductor device as in the present claims, including, after preparing a first raw material gas which contains a silane-based compound gas containing carbon atoms in a first hydrogen gas, and producing a first diluted raw material gas containing the silane-based compound gas with a second concentration lower than the first concentration by diluting the first raw material gas with a second hydrogen gas, supplying a first portion of the first diluted raw material gas into the inside of a reaction chamber in which is wafer to be processed is accommodated, with a remaining, second portion of the first diluted raw material gas not being supplied to the inside of the reaction chamber, this remaining second portion being discharged without flowing through the reaction chamber. See claim 1.

As will be discussed further infra, it is respectfully submitted that even assuming, arguendo, that the interpretation by the Examiner of the teachings of Sukegawa, et al. were correct, Sukegawa, et al. does not disclose, nor would have suggested, alone or in combination with the teachings of Takahashi, et al., wherein the remaining second portion of the first diluted raw material gas is not supplied to the inside of the reaction chamber, and is discharged without flowing through the reaction chamber.

Furthermore, it is respectfully submitted that the teachings of these references as applied by the Examiner would have neither disclosed nor would have suggested such a manufacturing method of a semiconductor device as in the present claims, having features as in claim 1 as discussed previously, and, in addition, having features as in the claims being considered on the merits in the above-identified application, including wherein the remaining, second portion is discharged from a

vent line (see claim 21); and/or wherein the first and second hydrogen gasses have substantially the same concentration composition (see claim 3), with purity of the second hydrogen gas being 99.99% or more (see claim 4); and/or wherein the reaction chamber is an epitaxial layer forming reaction chamber of a single wafer epitaxial device (see claim 5); and/or wherein the epitaxial layer formed constitutes a portion of a base region of a HBT (see claim 7) or is a channel region of a strain SiGe-based MISFET (see claim 8); and/or degree of dilution of the first diluted raw material gas as in claims 9-12; and/or first concentration of the silane-based compound gas containing carbon atoms in the first hydrogen gas, as in claims 17-20.

The present invention is directed to a manufacturing method of a semiconductor device, effectively applicable to manufacturing a semiconductor device having SiGe:C formed using an epitaxial growth technique.

Various techniques have been proposed previously for producing, inter alia, SiGe:C, as described on pages 1 and 2 of Applicants' specification. SiGe:C can be used not only as material of, e.g., a base of a HBT, but also as a material of a channel of a MISFET, described in the paragraph bridging pages 2 and 3, and in the paragraph bridging pages 3 and 4, of Applicants' specification.

However, in forming SiGe:C by an epitaxial growth technique, oxygen-based impurities are detected in the formed product; and, as described in section [0009] bridging pages 4 and 5 of Applicants' specification, it has been found that the concentration of the oxygen-based impurity depends on the C concentration or the Ge concentration, and concentration of oxygen-based impurity is increased corresponding to an increase of the C concentration or the Ge concentration. Inclusion of such oxygen-based impurity raises various problems. For example, when SiGe:C is used as a material of the base of a HBT, a lifetime of a carrier is

reduced due to the oxygen-based impurity. Further, in SiGe:C, a stacking defect or the like attributed to the oxygen atom, a point defect, a line defect or a face defect is induced, and a current flows along an interface of the defect; this current cannot be controlled with a bias, and becomes a leaked current. Accordingly, use of SiGe:C in the base of the HBT or in the channel of the MISFET deteriorates reliability such as a breakdown strength of the HBT or the MISFET. Note section [0011] bridging pages 5 and 6 of Applicants' specification.

Against this background, Applicants provide a method avoiding problems as discussed previously, wherein concentration of the oxygen-based impurity contained in the SiGe:C which is formed by an epitaxial growth is reduced. Applicants have found that by performing the diluting as in the present claims, concentration of oxygen-based impurity can be reduced; and even when the formed SiGe:C is used as the material of the base of the HBT, it is possible to prevent lowering of a lifetime of a carrier attributed to the oxygen-based impurity, and, as a result, it is possible to enhance the hFE. Applicants have found that, even when the SiGe:C formed by the present invention is used as the material of the base of the HBT or the channel of an MISFET, a crystal defect attributed to oxygen atoms can be reduced, and, hence, a leaked current can be reduced, thus enhancing breakdown strength. Note section [0020] bridging pages 23 and 24 of Applicants' specification.

Thus, according to the present invention, the oxygen-based impurity contained in the formed SiGe:C can be reduced, without reducing the concentration of Ge or the concentration of C. Note sections [0044] and [0045] on pages 40-42 of Applicants' specification.

Furthermore, by supplying the first portion of the first diluted raw material gas into the inside of the reaction chamber, with a remaining second portion not being

supplied to the inside of the reaction chamber, this second portion being discharged without flowing through the reaction chamber, gas flows can be more accurately and precisely controlled, further avoiding increase of oxygen-based impurity without reducing Ge and/or C.

Sukegawa, et al. discloses a method of growing a mixed crystal layer, suitable for use in the vapor phase epitaxial growth of a silicon-germanium mixed crystal layer doped with carbon and boron as a base layer of a hetero-junction bipolar transistor. This patent document discloses that when the silicon-germanium mixed layer is grown using a silicon source gas, a germanium source gas, a first impurity source gas such as boron, and a second impurity source gas such as carbon for inhibiting the diffusion of a first impurity in the mixed crystal layer, the concentration of the second impurity is equal to or higher than the concentration of the first impurity in a region at any given depth of the silicon-germanium mixed crystal layer. Note sections [0004] and [0013] on page 1 of Sukegawa, et al. See also Fig. 1 and the description in sections [0047] and [0048] on page 3 of Sukegawa, et al. Note disclosure therein that a gas supply pipe 12 is connected to the reaction chamber 1; and to the gas supply pipe 12, a gas cylinder 13, a massflow controller 18, and a valve 23, which compose a silicon (Si) source gas supply unit, a gas cylinder 14, a massflow controller 19 and a valve 24, which compose a germanium source gas supply unit, a gas cylinder 15, a massflow controller 20, and a valve 25, which compose a boron source gas supply unit, and a gas cylinder 16, a massflow controller 21, and a valve 26, which compose a carbon source gas supply unit, are connected in parallel via a valve 28, the valve 28 being connected to a dry pump 8 via a gas exhaust pipe 29, and selects whether to supply the respective source gasses to the reaction chamber 1 via the gas supply pipe 12 or exhaust them.

It is respectfully submitted that Sukegawa, et al. would have neither taught nor would have suggested such process as in the present claims, wherein a remaining second portion of the first diluted raw material gas is not supplied to the inside of the reaction chamber, and is discharged without flowing through the reaction chamber.

In the paragraph bridging pages 2 and 3 of the Office Action mailed August 19, 2008, the Examiner contends that in Sukegawa, et al., a remaining second portion of the first diluted raw material gas is not supplied to the reaction chamber, the Examiner noting that some portion of the mixed gas always remains in the gas supply pipe when the SiGe:C layer is growing. It is respectfully submitted that the Examiner has provided no basis for the conclusion that some portion of the mixed gas will always remain in the gas supply pipe, when the SiGe:C layer is growing, particularly in light of avoiding waste of the gasses. In any event, even if “some portion” of the mixed gas will remain in the gas supply pipe 12 in Sukegawa, et al., when the SiGe:C layer is growing, it must be transferred to the reaction chamber 1, as gas supply pipe 12 is connected at the downstream end to reaction chamber 1, and thus would not be discharged “without flowing through the reaction chamber” as in the present claims.

In any event, it is noted that the present claims recite that the remaining portion of the first diluted raw material gas is discharged without flowing through the reaction chamber. It is respectfully submitted that Sukegawa, et al. would not have taught, nor would have suggested, such additional feature recited in the present claims, and advantages thereof for more precise control of introduced gasses.

Particularly noting disclosure of the gas supply pipe 12 in Sukegawa, et al., it is respectfully submitted that the disclosure of this reference would have taught away from that aspect of the present invention wherein a remaining second portion of the

first diluted raw material gas is not supplied to the inside of the reaction chamber, and is discharged without flowing therethrough.

It is respectfully submitted that the additional teachings of Takahashi, et al. would not have rectified the deficiencies of Sukegawa, et al., such that the presently claimed invention as a whole would have been obvious to one of ordinary skill in the art.

Takahashi, et al. discloses a method for growing a semiconductor film on a substrate using gasses, the method including steps of growing a doped semiconductor layer epitaxially over a substrate by supplying, onto the substrate, not only a source gas but also a gas containing a dopant by pulse flow at least once; forming a gate electrode on the doped semiconductor layer such that the gate electrode makes Schottky contact with the doped semiconductor layer; and forming source and drain electrodes on right- and left-hand sides of a gate electrode over the doped semiconductor layer such that the source and drain electrodes make ohmic contact with the doped semiconductor layer. Note the paragraph bridging columns 4 and 5 of this patent. See also column 3, lines 28-55, and column 4, lines 30-49. Note also Embodiment 2 in columns 12-14 of this patent, particularly from column 12, line 66, through column 13, line 36.

Even assuming, arguendo, that the teachings of Takahashi, et al. were properly combinable with the teachings of Sukegawa, et al., such combined teachings would have neither disclosed nor would have suggested the presently claimed invention, including, inter alia, wherein a remaining portion of the first diluted raw material gas is not supplied to the inside of the reaction chamber and is discharged without flowing through the reaction chamber; and/or other features of the present invention as discussed previously, and advantages thereof.

In view of the foregoing comments and amendments, reconsideration and allowance of all claims being considered on the merits in the above-identified application are respectfully requested. In addition, upon allowance of claim 1, re-joining of the withdrawn claims 6 and 13-16, with allowance of these withdrawn claims in the above-identified application, are respectfully requested.

To the extent necessary, Applicants hereby petition for an extension of time under 37 CFR 1.136. Kindly charge any shortage of fees due in connection with the filing of this paper, including any extension of time fees, to the Deposit Account of Antonelli, Terry, Stout & Kraus, LLP, Account No. 01-2135 (case 1374.46346X00), and please credit any overpayments to such Deposit Account.

Respectfully submitted,

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